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Tacit knowledge management in a testing services company

Olli-Pekka Palmu

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ABSTRACT

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In knowledge management, tacit knowledge is knowledge acquired by the employees that is complicated to codify yet essential for companies offering services. As businesses grow and strategies shift, tacit knowledge must be managed correctly and continuously. Otherwise critical information may be misplaced or lost, leading to impacts on the business.

The purpose of this study was to identify how tacit knowledge could be efficiently managed, retained and shared in a global testing services company. The study's desired outcome was to identify potential deficiencies and to propose updates for these practices.

Data was obtained by researching the existing guidelines in company's quality management system, using online questionnaire sent to the personnel and conducting semi-structured interviews with chosen individuals. The study focused on a specific department of the company.

Respondents to the questionnaire and interviews had similar perspectives; answers indicated lack of cohesive definition of the guidelines in use at the company. Insufficient training was also identified as a major source contributing to the variable level of knowledge.

The findings indicated the need for improvement in knowledge management in the company. As a conclusion of the study, recommendation of defining the structure and level of detail of the guidelines is recommend as priority action. For further study, increasing the participant quantity, further usage of the Delphi method in additional cycles and the impact of suggested practices was suggested.

Key words: tacit, explicit, knowledge, management, process, quality system

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ABBREVIATIONS AND TERMS

TAMK	Tampere University of Applied Sciences
KM	Knowledge Management
SOP	Standard Operating Procedure
DIKW	Data, Information, Knowledge, Wisdom
ICT	Information and Communications Technology
SECI	Socialisation, Externalisation, Combination, Internalisation
HR	Human Resources
QAP	Quality Assurance Plan
VOIP	Voice over Internet Protocol
APAC	Asia-Pacific
GDL	Guideline
OE	Operational Efficiency

1 INTRODUCTION

1.1 Background

Knowledge is a wide-ranging concept, which can involve various individuals, processes, principles and systems. Knowledge can be divided to tacit and explicit knowledge, key differences being tacit knowledge is known only to the individual whereas explicit knowledge is codified knowledge, available to everyone within the organisation.

Conformance testing as a global industry utilises testing and certification requirements, specifications, test plans and guidelines from authorities. These authorities can be industry-specific authorities operating within limited geographical scope or global authorities with various scopes. In conformance testing companies, the work is performed by making a series of measurements and tests to provide evidence for the compliance of products in question to aforementioned requirements. The testing work can be done manually by utilizing tools such as multi-meters, oscilloscopes and vector network analysers or by analysing the source code semi- or fully automatically through specific tools to produce measurement results.

Knowledge of the personnel performing the measurements is crucial as conditions of the measurements, status of the tools used or status of the devices under testing need to be understood and taken into account by the personnel, otherwise measured results may be meaningless. Even though the measurement tool may automatically state whether the measured result is compliant to requirements, the initial setup for the measurement is done by the personnel and thus leaving room for interpretation if not all aspects are taken into account. Within the company, the knowledge exists in organisational structure and principles, but the services offered by the company rely heavily on the experience and expertise of the personnel of the company.

This thesis aims to address and improve tacit knowledge management in a global testing, consulting and solutions company. The thesis will focus on the testing department within the global company. The scope for the thesis arose from my

personal experiences within the company. My position as a local and regional manager has allowed me to observe testing activities performed regionally and globally, by both senior and new staff, so my perspective covers a wide scope of the activities within the company. In the recent years during which the company has expanded rapidly and globally, it has sourced new customer segments, changed ownership and recruited many new staff. At the same time, some existing staff either have obtained new responsibilities of other activities or have left the company.

As the company offers services to customers, personnel are one of the most important resources of the company. Many customers have a very long relationship with the company so even with personnel changes; both at customer and company side, customers expect the service level to be retained at a high level. If the service does not satisfy the requirements of the customers, it can lead to the following actions: the customer complains to address the issue or the customer sources a new supplier of testing services. Customer behaviour can be different depending on culture and geographical location of the customer, so localised knowledge and customer service experience is a valuable asset for the company.

All staffing changes can put the customer service experience at risk unless due care is taken. For the onboarding process, training of the new staff is extremely important. While the company has Standard Operating Procedures (Testing services company, 2017) to address major needs and an existing quality system with associated guidelines for the actual work, senior employees continue to hold a substantial amount of important tacit knowledge, which is beneficial to other employees.

1.2 Research objective

The objective of this research is to identify suitable and realistically implementable ways to globally and locally manage the tacit knowledge in the company. The research question proposed in this study is the following:

How can tacit knowledge be efficiently managed, retained and shared?

As continuous improvement is essential in the services industry, this thesis provides improvement suggestions related to company procedures, guidelines, instructions and best practices, which can be implemented via existing databases or by potentially utilising a proprietary data management tool.

Research was conducted utilising questionnaire and interviews with junior level employees, senior level employees and expert level employees. The study focuses on a specific department of the global company, but as some of the outcomes cover improvements to the processes, such improvements can also be utilised in other departments of the company as a guideline to improve relevant processes. As the company has several regional offices, the questionnaire was disseminated utilising a global mailing list, and interviews have been done as globally as possible. Thus, the most global perspective was obtained for the research question.

1.3 Scope of study

While the company offers services within the testing, consulting and solutions domain, the scope of this thesis is limited to the testing services department. Within the testing services department, there are various different testing activities, separated by teams and geographical locations. The respondents participating in this study were based in specific teams originating from Canada, China, France, South Korea and Taiwan. Respondents were asked to provide their viewpoints on the customer journey within the department, to identify potential points which lack sufficient standardisation and finally to provide their own suggestions of the improvements.

As the research results are not specifically limited to any specific testing activity, the results of the research work can potentially be implemented to all testing services and also other services offered by the company. This research does not mandate any entity to implement any of the findings. Rather, the results are provided as suggestions which department managers can choose to implement. The follow-up of the implementation of the findings is also not part of this research as

different geographical entities of the company have their own decision-making structures, timelines and priorities to follow.

The research is limited to the operational level (production and mid-management) to focus on practical everyday aspects directly linked to the customer service of the company. As the services provided by the company in its various regional offices are based on the same standards, specifications and Standard Operating Procedures, local and global knowledge must be at the same level. Otherwise, regional differences will occur, leading to imbalance on the customer service level. Such imbalance can have negative impacts if a customer experiences the same testing service being offered differently (faster, slower, with more or less information) in two or more different locations.

1.4 Thesis Structure

This thesis is divided into five segments, which are visualised in Figure 1:

- Theory
- Current status of the company
- Research methodology
- Results
- Conclusion

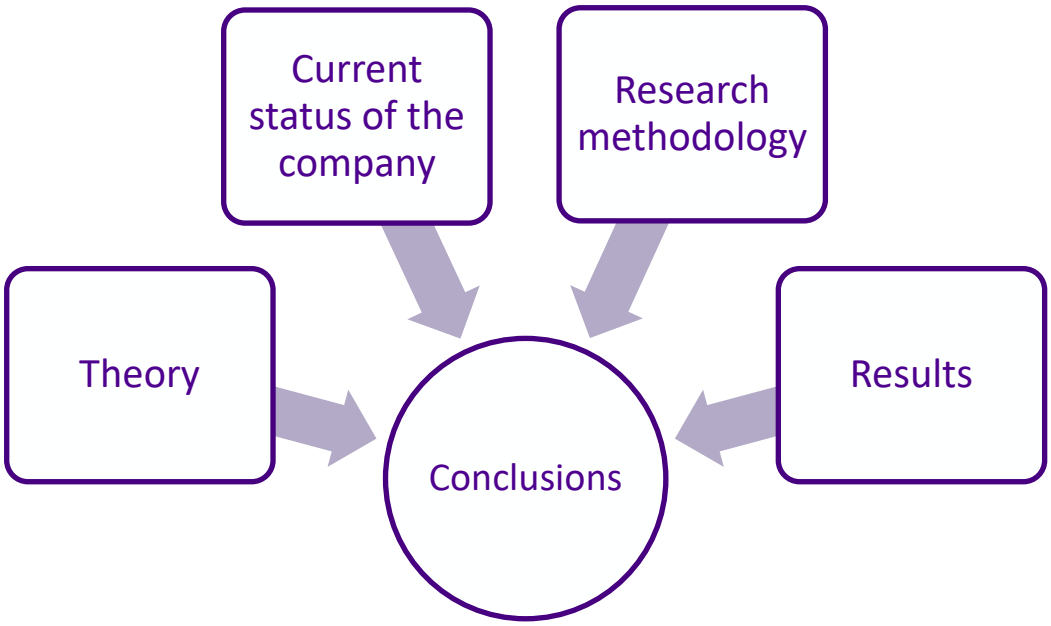

FIGURE 1. Structure of the thesis

In Chapter 2, Theory, various knowledge management theories are indicated that provide frame work for the research. Selection of these theories are utilised in the Chapter 4.

In Chapter 3, Current status of the company, examines the current status of the knowledge management in the company with indications on particular points which will approached in the Chapter 5.

In Chapter 4, Research methodology, research theories are introduced and the questionnaire and interviews are presented which will be used to obtain global view from the production level at the company.

In Chapter 5, Results, the findings originating from the questionnaire answers and interviews are presented. This chapter also includes suggestions for the recommended steps to answer to the research question.

In Chapter 6, Discussion, closing arguments and analysis of the study are presented.

2 THEORY

2.1 Chapter overview

To discuss knowledge management, the concept shall be divided into two components: knowledge and its management. Further differentiations shall be also made between the definitions of knowledge, information, data. In the following sections these definitions are introduced, in addition to other pertinent topics such as organisational knowledge, knowledge sharing, tacit knowledge, human and social capital and knowledge conversion methodologies.

2.2 Data, information and knowledge: definitions

The concept of the data-information-knowledge hierarchy has been known since the 1950s, but within the knowledge and management community it is generally agreed that the first publication on the concept was made by Russell Ackoff in his article written for Journal of Applied Systems Analysis (Ackoff, 1989, pp. 3-9). Ackoff's DIKW (data, information, knowledge, wisdom) hierarchy is visually interpreted in Figure 2. Ackoff himself never made a graphical representation of the pyramid so the visualisation is created for clarification. Wisdom is not represented in the pyramid; as this research is related to knowledge management in the technical industry, the concept of wisdom is beyond the scope of this research because typically, wisdom represents highly subjective topics such as principles and morals of an individual. While wisdom is important for competency of an individual, these attributes would be too complex to translate into a tangible set of recommendations, which the thesis aims to provide.

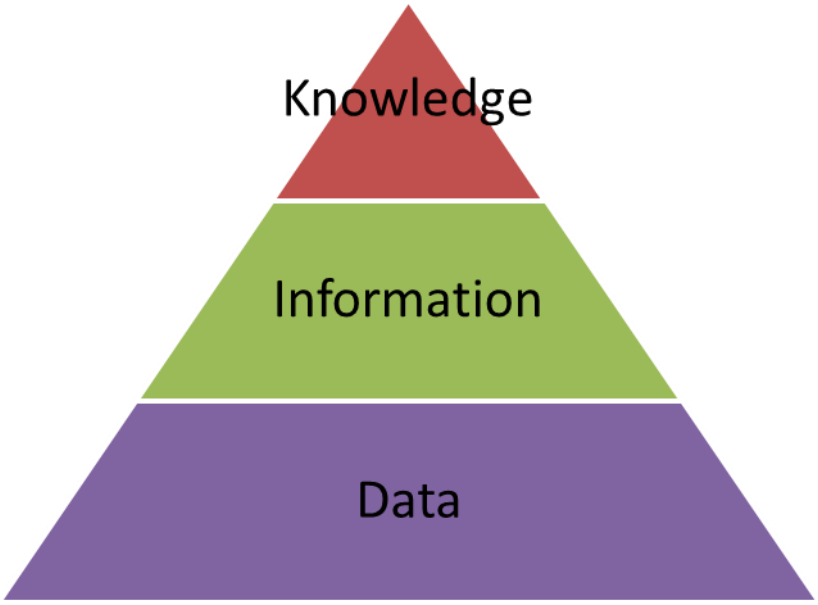

FIGURE 2. Data, information and knowledge relationship based on (Ackoff, 1989), modified

Information and knowledge tend to be used quite interchangeably despite being somewhat different. However, the definition of data is less argued as there is a generally accepted view: data is simple, raw and unprocessed facts or figures. It is also generally agreed by scholars that data is something less than information, and information is something less than knowledge.

Information is defined as something factual or a flow of messages (Nonaka & Takeuchi, 1995, p. 71). Knowledge is defined by the same authors as belief, commitment and meaning. While (Davenport & Prusak, 2000, p. 2) describe data as a set of discrete and objective facts about events, they characterise information as messages in the form of a document or audible or visible communication. Information is also data with a meaning. Davenport and Prusak define knowledge (Davenport & Prusak, 2000, p. 2) as a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences. While some variance exists in the definitions, they all fit into the concept and structure of Ackoff's hierarchy.

While being the most commonly referred, DIKW-hierarchy is not without opponents, such as (Tuomi, 1999, p. 10) who argues that the DIKW-pyramid should be inverted: "Information can be only created from knowledge; data emerges as

a by-product of artifacts that assume the existence of socially shared practice of using these artifacts". Tuomi's argument of data is more than knowledge includes an example of a thermometer, an artifact conventionally understood as manmade object, which, as a tool used to collect data on temperature, fixes the relations that define what temperature is based on the knowledge used to build the thermometer. If mankind does not know how to build a thermometer, mankind is not able to measure the temperature.

Jennex, another opposer of the DIKW hierarchy, (Jennex, 2009, p. 1), argues that it is too simplified. In DIKW hierarchy, wisdom is placed on top of the pyramid, as a smallest component and data at the bottom as a largest component. Therefore, Jennex proposes an inverted pyramid in more complexity to suite the modern world by introducing interactions between various parts of the hierarchy. In Jennex's model, the data is the smallest segment and wisdom the largest. He argues on page 3 of his article:

> If information is the structuring of data into meaningful combinations, then the number of possible combinations for a quantity x of data is minimally x.

This approach implies that the processing of data can create a higher volume of information than the source data by using different frames of reference. Such different frames of reference are described by Jennex as accountants versus marketers of engineers versus biologists.

My opinion is that these debates on the order, structure and validity of the DIKW hierarchy seem quite philosophical. My personal and somewhat simple definition of the trio of data, information and knowledge is that data is something obtained by measuring it with something, information is knowing what the obtained data means and knowledge is knowing what to do with the data and information, such as knowing why to use it and how to use it. I'm therefore agreeing with Tuomi's argument of the inverted DIKW hierarchy, as the scope of this study is done on the field of testing, measuring devices with instruments. Typically, the product a testing company produces is a testing report which contains data and observations from performed measurements. It is important to know these definitions and their relations to each other, even though the actual research work in this study

doesn’t tackle philosophical issues but more pragmatic technical and organisational issues.

2.3 Organisational knowledge

Rather than general knowledge, we are going to focus on organisational knowledge as it pertains to the objective of this research. Organisational knowledge is defined as “information that is relevant, actionable, and based at least partially on experience (Leonard & Sensiper, 1998). Therefore, employees’ decisions and actions based on their interpretation of data contribute to the knowledge of the company. This data can be processed in a multitude of ways, creating new knowledge (Baumard, 1999, p. 16). We can see that organisational knowledge originates from the personnel of the company. It is worth noting that the values of the personnel can impact organisational knowledge. As these values are highly subjective, they result in potentially biased perspectives of organisational knowledge. Organisational knowledge can be rigid and well-defined or in constant change.

2.3.1 Knowledge infrastructures of the organisation

(Gold, et al., 2001, pp. 187-189) introduce three infrastructures, technical, structural and cultural, which are all linked to maximizing organisations capability and capacity. Technical infrastructure refers to the ICT-systems in place in the organisation and the usage of those systems. The structure of the organisation plays a vital role in how the organisation values the individuals or units within the company. For example, if the structure of the company lacks rules on how to utilize technical infrastructure or if information sharing is not encouraged, it will have a negative impact on organisational knowledge. The same effect applies vice versa. Lastly, organisational culture refers to corporate vision, values, employee interaction and collaboration, all of which have major impacts on organisational knowledge. These three aspects are related to the existing management of knowledge in the organisation.

External knowledge, or knowledge that does not yet exist at the organisation, is an important part of the organisation knowledge. According to (Gold, et al., 2001, pp. 190-192), four steps are linked to the external knowledge management process: acquisition, conversion, application and protection, which is somewhat similar to (Nonaka & Takeuchi, 1995, p. 75) tacit knowledge conversion process, as shown in the later section 2.8. Acquisition refers to how the knowledge is obtained, conversion refers to organizing or structuring the knowledge to the company systems, application refers to the usage of the knowledge and protection refers to the prevention of theft or inappropriate use.

The following Figure 3 indicates the visualisation of the terms defined by (Gold, et al., 2001). All items together form the basis of effective organisation.

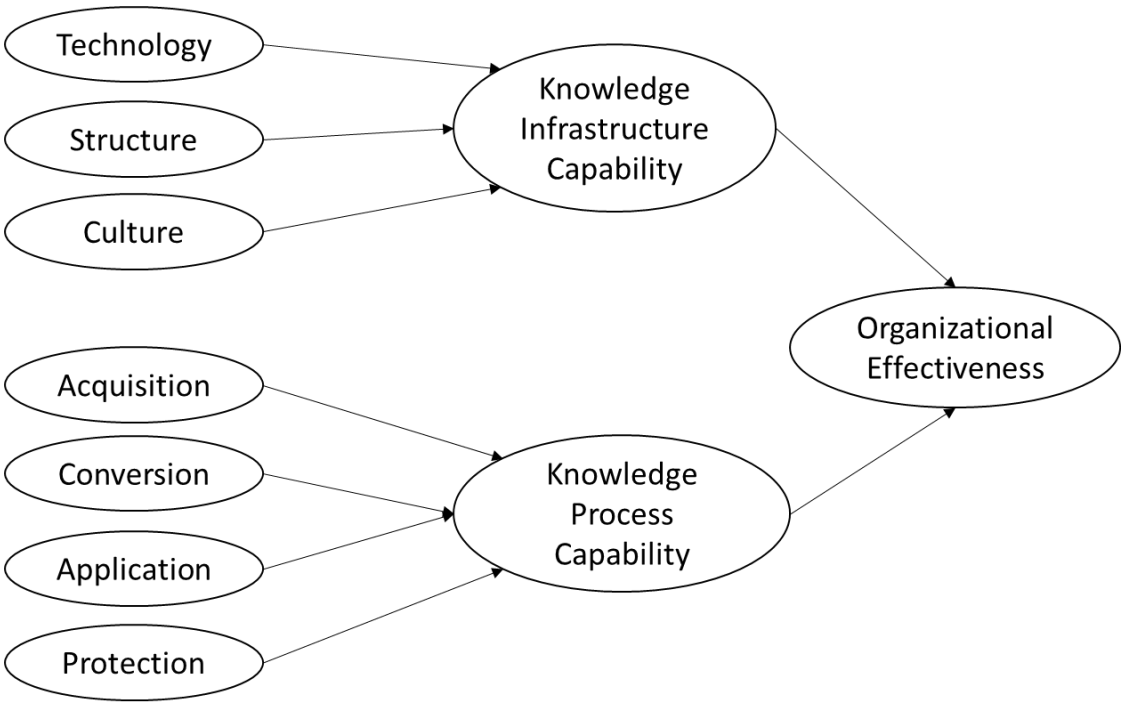

FIGURE 3. Knowledge management Capabilities and Organisational Effectiveness (Gold, et al., 2001)

2.4 Knowledge management: definitions

Numerous studies have been conducted on knowledge management and its definition. For example, the definition of knowledge management according to (Edvardsson, 2004) relies on organisation practices and approaches regarding generating, capturing, disseminating and using knowledge relevant to the organisation's business.
(Hislop, 2004, p. 56) defines the knowledge management as the following:

> Knowledge management is an umbrella term which refers to any deliberate efforts to manage the knowledge of an organization's workforce, which can be achieved via a wide range of methods. Including directly, through the use of particular types of Information Communication Technology (ICT), or more indirectly through the management of social processes, the structuring of organizations in particular ways or via the use of particular culture and people management practises.

There is another definition by (Gephart, et al., 1996, pp. 34,35): Knowledge management refers to the process of enhancing company performance by designing and implementing tools, process, systems, structures, and cultures to improve the creation, sharing and use of knowledge.

As this study is performed in technical field, the usage of ICT is linked to most of the steps of knowledge management. Instructions are codified into the database, measurement devices are recording data to the hard drive, results are stored in a database, reports are stored in servers and messaging is done via emails or short messages. The only non-ICT portion of knowledge management is the tacit knowledge, residing in personnel. With these perspectives, knowledge management seems to address key issues regarding how a company can efficiently manage the information it already possesses and how a company is able to compile all of its existing information before doing so.

2.5 Knowledge sharing

The most fundamental element in knowledge management is knowledge sharing, as without shared knowledge, knowledge management means only individual personnel management. The importance of knowledge sharing varies depending on the type of enterprise, but it is especially crucial within service-oriented companies because personnel are providing services based on their knowledge. By efficiently sharing the knowledge, companies will be able to obtain different objective viewpoints from the individuals offering and receiving the knowledge, thus improving internal and external processes.

Answering to the question of why knowledge is not shared efficiently and proactively everywhere is multi-faceted. A possible answer is that, depending on the company culture, senior employees may consider keeping certain critical knowledge to themselves by not codifying it in any way to make themselves invaluable to the company. Such behaviour can occur due to management style, colleagues or company strategy. Knowledge sharing can be linked to loss of human capital, as the reasons for lack of knowledge sharing can be similar as reasons for departure from the company, as described in the following section 2.6.

2.6 Human capital and social capital

If a person with critical knowledge leaves the company, it is not only the loss of human capital (Dess & Shaw, 2001) but also the potential loss years or decades of knowledge. According to (Dess & Shaw, 2001), human capital is a primary determinant of productivity and, consequently loss of human capital equates to decreased productivity (increased turnover). It could also lead to total loss of productivity if critical equipment maintenance is not performed due to a lack of knowledge.

As suggested by Dess and Shaw, employee turnover will negatively affect company performance through the loss of social capital. Social capital is defined by (Leana & Van Buren, 1999) as “a resource reflecting the character of social relations within the organisation, realised through members’ levels of collective goal

orientation and shared trust". Social capital is tacit by definition and thus a critical organisational resource. It should be protected against loss.

Various reasons contribute to a knowledgeable employee's decision to leave the company: a lack of personal challenge, loss of motivation, company culture, management, peers, industry trends or friends and family. Organisations have many tools in their disposal for prevention of loss of human or social capital but depending on the structure of the organisation, these tools may not be applied correctly or may not be applied in due time. Direct managers and HR have a key role in this loss prevention so these two entities should work seamlessly on personnel management.

2.7 Tacit knowledge

The adjective tacit, as per (Oxford University Press (OUP), 2019) describes that which is understood or implied without being stated. Following this, tacit knowledge would refer to knowledge that is not written. The opposite of tacit knowledge is explicit or codified knowledge, which is written.

One of the most important authors on the matter of knowledge, Michael Polanyi, discusses tacit and explicit knowledge in his publication (Polanyi, 1958, p. 55). Tacit and explicit knowledge are integral parts of knowing, and tacit knowledge is a vital part of visible knowledge. This is reflected in the knowledge process of apprenticeship as explained by Polanyi:

> By watching the master and emulating his efforts in the presence of his example, the apprentice unconsciously picks up the rules of the art, including those, which are not explicitly known to the master himself.

In other sources, tacit knowledge has been described by (Zack, 1999) as the following: subconsciously understood and applied; difficult to articulate; developed from direct experience; and usually shared through highly interactive conversation, storytelling and shared experience. According to (Nonaka & Takeuchi, 1995, p. 21), tacit knowledge consists partly of technical skills and 'know-how',

but the person is often unable to articulate the scientific or technical principles behind what he knows.

Tacit knowledge, as it relates to the individual, is subjective and personal knowledge. Ordinarily, personal knowledge can be improved by social dynamics, such as conversing and demonstrating. Ultimately, either personal tacit knowledge remains as personal knowledge or it becomes group or social tacit knowledge. In organisations, for example, a team of experts can maintain social tacit knowledge, which perhaps originated from one individual. Such teams of experts are highly valuable to any organisation as the tacit knowledge they hold can be decades-old and the team may be constantly improving that knowledge. When comparing junior or less-experienced employees to experts, experts are more accurate in decision-making, deducing conclusions, preventing issues and reacting faster to issues (Kuronen, et al., 2007, p. 12).

Organisations need to make the decision of whether to keep the tacit knowledge as it is and develop ways to share it or to convert the tacit knowledge to explicit knowledge. In the conversion, some potential ways forward are introduced in section 2.8. The conversion process varies, from simple to complex. Typically, as the knowledge retained is individual, the codifying process takes time and money as generic boilerplates cannot be utilized in the conversion process.

From an organisational perspective, tacit knowledge retention is possible (Droege & Hoobler, 2003) when companies promote employee interaction, collaboration, diffusion of non-redundant (as in unique) tacit knowledge and characteristics of company's social network, which includes density and an optimal mix of weak and strong ties. When companies develop new products or services through knowledge application, the underlying tacit knowledge is at least partially recorded in the process. This type of action can be referred to as ownership.

Much knowledge can remain tacit for various reasons. According to (Leonard & Sensiper, 1998), one reason could be that the explication of the knowledge would not be beneficial. Another reason can be that unless an incentive is created, individuals possessing the tacit knowledge would rather keep it to themselves. If

knowledge remains tacit, this should not be interpreted as an issue in the organisation but rather an opportunity to develop suitable working models. Tacit knowledge sharing, beyond the previously mentioned advantages of knowledge sharing, can improve teamwork, team spirit, employee interaction and team efficiency. As described in (Kuronen, et al., 2007, pp. 22-28), tacit knowledge sharing methods like apprenticeship, multi-skilled teams, mentoring, team mentoring, site visits, observations, case studies, meetings, peer learning, expert networking, simulations, and rotation of tasks are useful ways for organisations.

2.8 Knowledge conversion with SECI-model

Knowledge creation, through which tacit and explicit knowledge are combined and organisational knowledge is created can be visually explained by utilising the knowledge conversion (Nonaka & Takeuchi, 1995, p. 74) SECI-model (Socialization, Externalization, Combination, Internalization), as described and demonstrated in the following (Figure 4). The flow of the SECI-model can be explained with the following order:

- Socialization (tacit to tacit)
- Externalization (tacit to explicit)
- Combination (explicit to explicit)
- Internalization (explicit to tacit)

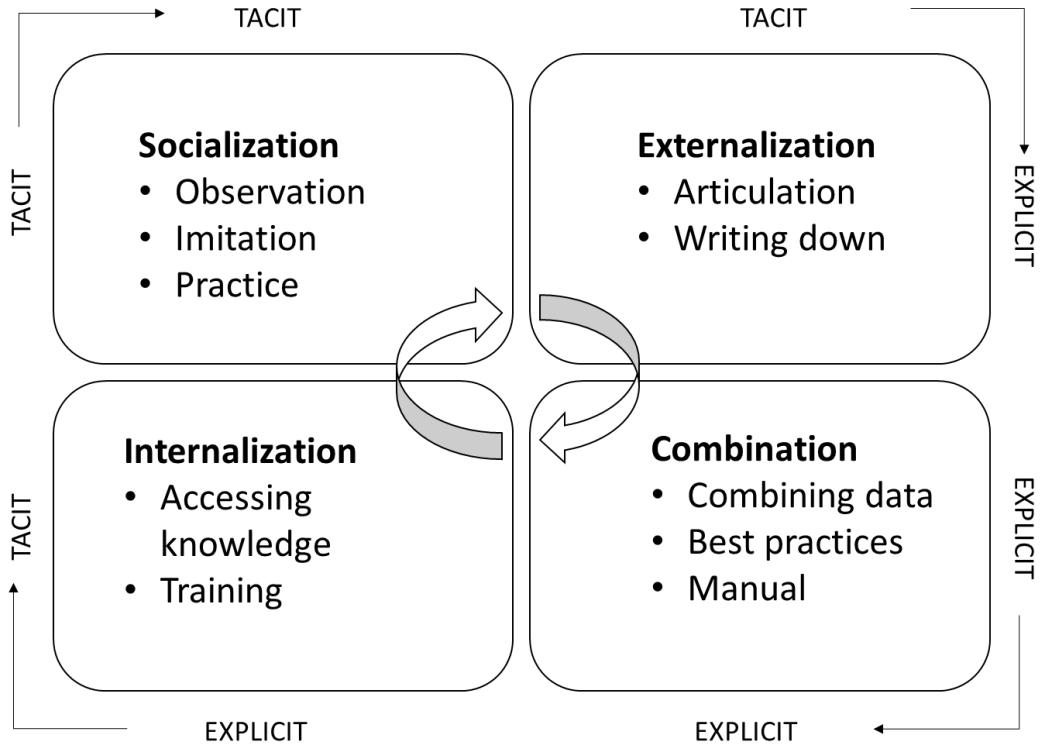

FIGURE 4. Nonaka's knowledge spiral (SECI), (Nonaka & Takeuchi, 1995, p. 75), modified

Socialization refers to the sharing or observing of tacit knowledge face-to-face. Typical examples of this are apprenticeship, during which the master teaches the student through hands-on experience, and learning to ride a bicycle by observing how another person rides a bicycle (Harorimana, 2010, p. 30). Typically, this step has some cultural variance depending on the location of the company. For example, Japan tends to be more collectivist and Western countries are often more individualist.

Externalization refers to the articulation of the knowledge. Typical examples are writing notes, creating images and concepts and explaining the importance of keeping balance to those learning to ride a bicycle (Harorimana, 2010, p. 30). As mentioned by (Nonaka & Takeuchi, 1995, p. 77), this step also involves collective reflection, so an individual would not just write something down.

Combination refers to the action of combining different types of explicit knowledge from various sources. This combined knowledge then becomes new knowledge

to be distributed within, for example, an organisation. Following the bicycle example, this step would involve combining texts about how to ride a bicycle with drawings illustrating it (Harorimana, 2010, p. 30). This step has considerable cultural variance. As mentioned by (Nonaka & Takeuchi, 1995, pp. 80,81), Japanese companies are more in favor of tacit knowledge whereas Western companies focus more on explicit knowledge. (Harorimana, 2010, p. 42) mentions that it is complicated to define what causes cross-cultural differences. They could stem from differing cognitive processes, national cultures or organisational cultures.

Internalization refers to the training and receiving of knowledge and applying the knowledge and skills. In the bicycle example, this step would be about practicing how to ride a bicycle and how it would improve the learner's skills and confidence (Harorimana, 2010, p. 30). This step, which increases value in an organization, relies heavily on the culture of the company to define the exact methods, rather than culture of the country.

After internalization step, Nonaka's SECI-model can continue with a new cycle on another level. For example, the new insights found in the first cycle can be leveraged in other process designs or product design within the organisation.

2.8.1 Redundancy

Nonaka and Takeuchi illustrate culturally specific concept in their study called redundancy (Nonaka & Takeuchi, 1995, p. 27). During the time of their study (1995) it was a fundamental principle in Japanese companies. Based on my personal experience in working with Japanese companies, it still applies today. According to Nonaka, redundant organisation, which refers to overlapping of company information, business activities and managerial responsibilities, is important because it encourages frequent dialogue and communication. Redundant organisation thus creates common ground between employees. It follows that, with such organisation, tacit knowledge sharing is more likely.

Such redundancy in today's many business environments, especially those outside Japan, is rare due to the application of lean operating philosophies. Hence,

redundancy should be sought in other ways. Nonaka indicates alternative methods for redundancy: strategic rotation and free access to company information. These are more feasible ways that can be applied in a wide range of companies. Several Chinese and Japanese companies follow the strategic rotation method by keeping their top management in rotation within the departments every two years. This has the advantage of efficient knowledge sharing but there are also disadvantages as the persons in charge will change frequently.

What I have experienced is that the challenges in the management rotation are related to finding a correct point of contact once every couple of years. As it is important to establish relationship with customers or authorities, having the contact persons replaced frequently makes relationship management fairly complicated.

Free access to company information is a powerful tool but requires compartmentalisation to prevent confidential information distribution (salaries, personnel files, intellectual property and so on). In a book called Principles (Dalio, 2017, p. 136), a term radical transparency is used heavily. Radical transparency refers to sharing all possible material within the company to every possible employee. Ray Dalio, the author of the book, uses radical transparency as a principle to manage his hedge fund investment company. As confirmed in the book, total radical transparency is ideal but not totally possible due to privacy requirements. The best way to apply it is by sharing all possible material with as wide of a range of staff as possible while expecting everyone to be held accountable for their thinking and actions regarding the information. According to Dalio, the main issue that should be focused on concerns the method of information sharing rather than the content of the information.

2.9 Other tacit knowledge conversion methods

(Kuronen, et al., 2007, pp. 29-32) summarise several methods for tacit knowledge conversion, few are mentioned here: storytelling, interviews and modelling. Storytelling is a social process that can be in oral, written, illustrated or other formats.

It can occur in one-to-one settings or in groups. Therefore, this can be used for not only knowledge sharing but also improving the co-working spirit.

Alternatively, interviews can also be used to share the tacit knowledge. This is a more formal process than storytelling as it involves preparing for the interviews, recording, transcribing, and analysing the process. Within the company, interviewing is typically done between junior and senior employees about the mutually known subject, such as technical process or specific step of work.

Lastly, modelling is a written process of the issue, factors contributing to the issue, the solution and results. Modelling is systematic but may not contain all relevant tacit information, as by definition modelling address the explicit part of the information.

2.10 Knowledge management strategies

According to (Hansen, et al., 1999, pp. 107-109), knowledge management can be divided into two strategies: codification and personalisation. In codification, knowledge is carefully codified and stored in databases that are accessible to the employees of the company. In personalisation, knowledge is tied to a person who developed the knowledge and can be shared mainly through one-to-one contacts. (Table 1) illustrates some key differences of the two strategies.

TABLE 1. Knowledge Management strategies (Hansen, et al., 1999)

	Codification	Personalisation
General	Computer-based system for storing & sharing codified data	Network of people available to share the knowledge
HR	College grads well-suited to use knowledge & solutions	Masters of Business Administration who like problem solving
Training	Group & distance learning	Mentoring
Resource usage	Computer networks	Personnel time
Rewards Systems	Reward people for using and contributing to databases	Reward people for directly sharing their knowledge with others

Choosing the appropriate strategy depends on the profile of the company. On the one hand, if a company offers mainly standardised services, a codification model is more efficient to utilise, as the data is readily available to be re-used. On the other hand, if a company offers mainly customised services, each tender requires modification. Therefore, a personalisation strategy is more suitable for such a company.

Interestingly, (Hansen, et al., 1999, pp. 112-114) advice caution when mixing strategies. According to them, the most efficient use of strategy is 80-20 split where 80% of the knowledge is following one strategy, 20% the other.

According to (Barnes & Milton, 2015), there are four focus areas for knowledge management. Figure 5 illustrates the focus areas.

FIGURE 5. The four business focus areas for knowledge management (Barnes & Milton, 2015)

Operational excellence focuses on knowledge within the organization. Strategies rely on continuous development and improving practices, innovation and standardization. Operational excellence relies heavily on codified knowledge. In the company investigated in this study, the operational excellence team has been adopted since 2018. The team is responsible for analyzing process and creating tools to help to simplify or expedite an offered service by automating tasks.

Customer knowledge refers to efficient customer relationship management. The customer interface must know, in detail, the customer, products and the market in order to efficiently generate high service level and sales. Competitor knowledge is also crucial as it provides additional perspective for the company to help drive decisions regarding for example service level or pricing adjustment. CRM (Customer Relationship Management) tools are typically used to codify this knowledge, also in the company investigated in this study.

Innovation focuses on external knowledge, which is used to create new services and improve existing services. External knowledge is typically obtained by participation in think thanks, market research and technology watches. Hiring of new

talent is also part of this strategy, as injection of new talent and different ways of thinking can improve innovation. The company investigated in this study participates and contributes to various technical working groups and task forces in order to keep up with the technological advancements and also in order to help drive innovation within the industry.

Growth and change focuses on replicating existing success within new environments, such as new staff or new markets. The company investigated in this study has expanded rapidly and successfully to new markets, both geographically and technologically, relying on known strategies familiar with the staff. Lessons learned and transferring of existing knowledge to new staff is crucial for this strategy.

According to (Barnes & Milton, 2015), choosing the appropriate strategy also depends heavily on the composition of the workforce. Globally speaking, staff's attitudes, demographic and education level all play their part in the equation. For example, experienced staff typically work well together with other experienced staff because their knowledge is at the same level, so their ideas and thoughts mutually inspire each other. The older workforce acts as the source of the knowledge, while the younger workforce should be the recipient of the knowledge. In this equation, it will be the company management's task to ensure this happens, globally and locally.

As this research is done for a multi-national company, cultural (both as a working culture and as a country-based culture) implications must be taken into account in knowledge management. Commonly agreed elements as detailed in (Harorimana, 2010, pp. 277-294) for a competitive company require some localisation in multi-national company to have full effectiveness:

- Training: a company needs to offer continuous training to its employees. In theory, continuous training is beneficial to the both individuals and the company but, in reality, budget constraints set limits to the amount of training a company can offer. Then, what to offer and to whom will be defined typically by one of the management staff. The amount of training required to achieve a specific level will also depend on the seniority of the team.

- Communication: how the information flows from management to personnel and vice versa. Depending on the country, it may be welcomed or frowned upon to question or challenge management. In either case, employees need to be informed of matters affecting them. In addition, the effect of communication will depend on both the organisation and country's culture. Employees may accept the communication (whether positive or negative) without comment or they may submit their resignation on the same day.

- Rewards: efforts related to knowledge management improvement are rewarded consistently. From my experience, there is a difference between Western companies and Asian companies. For Asian companies, rewards related to knowledge improvement or innovation are not easily obtainable or even commonly understood, whereas Western companies have more on-the-spot rewards. The frequency of rewards can have an effect on the volume of knowledge improvement suggestions company will receive.

2.11 Ownership of knowledge management

Knowledge management could be the responsibility of human resources, project managers, the information technology department, team managers or other staff. There is no clear answer to who should have ownership, as it would depend on the type of knowledge. An ideal solution for codifying the knowledge would be to have a database in which each person could input knowledge without a specific structure, and the database would then parse the data and record it to correct sections in the database through tools such as AI (Artificial Intelligence). This database would then be accessed by queries or question words.

As the persons requiring the knowledge also have knowledge in other areas, contribution and frequent updates to the common database is key. If a company only relies on old content with non-regular updates, there will be a risk of non-compliant service being provided. Current practices in the company investigated in this study handle essential data recording, such as updates originating from authorities. As soon as employees stop sharing information, it will have the impact of

stagnating the growth of the company. It is company management's responsibility to ensure company growth, and this can be achieved, for example, by making changes in company organisation structure or culture and by providing environments and opportunities for employees to learn, train and share their knowledge.

Employee involvement and engagement is undoubtedly crucial for knowledge sharing. If staff sees the knowledge sharing as an additional task in addition to their original work, willingness to offer it will be extremely low. A reward system can be a useful way to promote and propagate knowledge sharing. If the knowledge sharing is seen beneficial both to the source and the recipient of the knowledge, this will ensure the continuous positive cycle of sharing.

For knowledge management systems to be up-to-date and widely used, especially within the company investigated in this study, they need to fit to the following criteria:

- Comparably faster and more accessible than asking from a colleague.
- Up-to-date and accurate information at any given time.
- Data redundancy, as in no regional constraints for possible ICT-related downtimes.
- Containing the knowledge in sufficient level of detail for efficient application.

2.12 Chapter summary

This chapter introduced various definitions for knowledge and knowledge management theories. I have proposed my personal definition of the data-information-knowledge in section 2.2 as an inverted DIKW-pyramid, for it is logical to apply in the field of the company investigated in this study. Based on my experience at the company, the knowledge conversion theory currently applied is a variant of Nonaka's SECI-model. Nonaka's SECI-model offers benefits for multiple cycles of knowledge conversion which will be beneficial to the company with proper implementation. Section 2.10 provided a brief look into the company's operations

following (Barnes & Milton, 2015) four business focus areas for knowledge management. All of the introduced theories provide potential ways forward in the subsequent chapters to provide answer to the question introduced in section 1.2:

How can tacit knowledge be efficiently managed, retained and shared?

3 CURRENT STATUS OF THE COMPANY

3.1 Knowledge management within the company

The current status of the knowledge management in the company chosen as the subject of this study, as described in the subsequent paragraphs, is based on my experiences and observations as a local and regional manager. I have been involved in the usage and improvement of the relevant systems, tools and procedures and participated in internal and external audits of the said systems, tools and procedures. The following paragraphs provide a detailed overview of the current status which will be then further analysed in Chapter 4.

The company relies on the global quality system (Testing services company, 2017) and the knowledge of the employees to manage the testing services offered to the customers. The global quality system is divided into two components: non-technical quality materials (for example, project management and report issuance), which are located on cloud server and technical quality materials (for example testing methodology and device usage guidelines) which are located on a physical network server. This quality system is the backbone of the knowledge management in the company and has been evolving for more than 20 years. All employees have access to the non-technical materials whereas access to the technical materials is restricted based on the employee profile.

Senior employees, such as experts and activity managers, retain tacit knowledge on how a typical product or a subcomponent behaves with certain test items. This kind of knowledge is transferred case by case to junior employees (when asked or when a situation occurs), as the training plans used by junior employees cannot contain all the possible scenarios and details. Tacit knowledge of all the employees is only partly codified, utilising notes, worksheets, shared folders or emails. The lack of cohesiveness in knowledge management can negatively affect the service offering of the company.

As the company is a service provider, customers pay for the testing services. These services are performed by employees, typically engineers, utilising various

testing tools which are either develop in-house or purchased from external tool suppliers. As indicated in section 2.10, the operational excellence team at the company is assigned to create assisting tools, streamlining processes and overall improvements but knowledge management is not yet within that team's scope.

3.2 Staff structure

The company staff structure in the testing department generally follows the organisation chart as illustrated in Figure 6. There are some regional variances in role titles, such as Analyst, Technician, and Specialist but these roles generally correspond to some of the positions described in Figure 6.

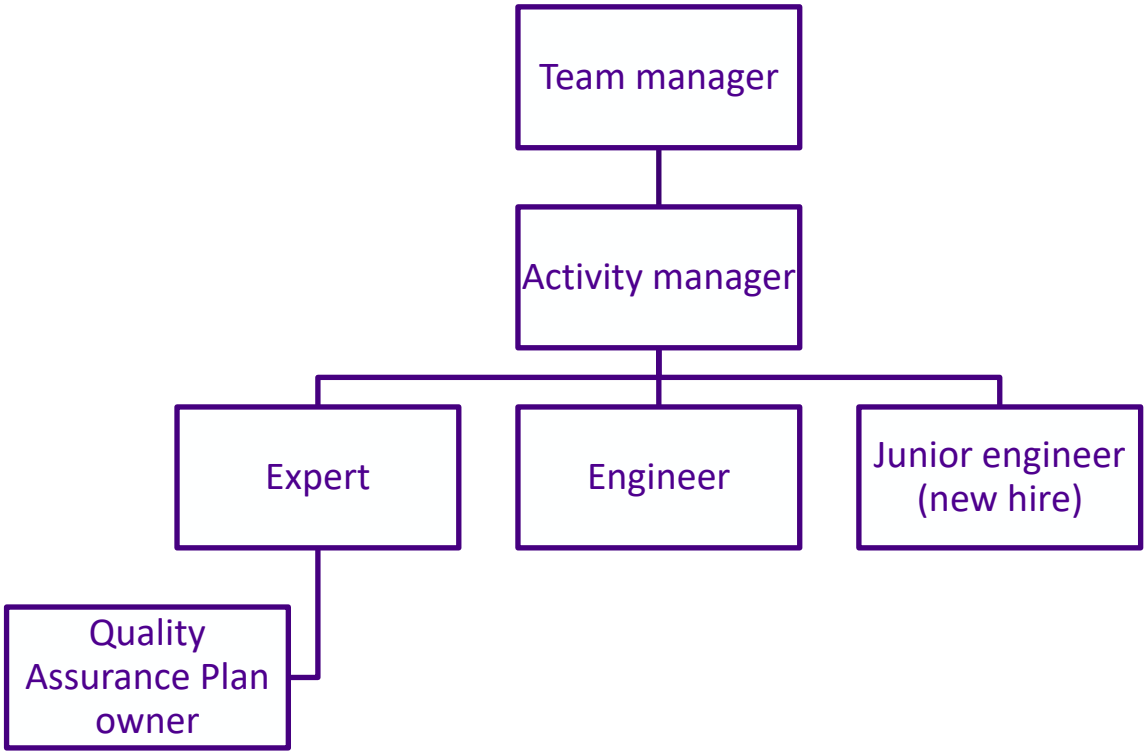

FIGURE 6. Staff structure

Junior engineers, as new hires, are described in detail in section 3.2.1. Engineers are qualified employees who have followed and completed training for at least for one activity. Such employees can make decisions autonomously, only consulting with senior employees if required.

Experts have completed several projects and thus have the knowledge and decision-making skills on practically all matters per their area of expertise. Experts, as QAP (Quality Assurance Plan) owners, also communicate with authorities regarding revisions of the processes if required before further communicating such updates to other staff globally.

Activity managers are responsible for the team working under them, typically consisting of several experts and engineers. In most cases, activity managers were previously experts. The team manager manages one or several activity managers depending on the size of the team. The team manager has upper managers but as they are outside the scope of this thesis, they are not included in the organisation structure above.

Advancement from one position to other depends on certain criteria, such as completing a sufficient amount of projects without issues or having a suitable mindset for staff management. Generally, experts have at least five years of experience, while most of their seniors more than 20 years of experience.

3.2.1 Employee training

When the company is looking to hire new employees, candidates' knowledge and knowhow of the industry is typically measured using an initial exam (Testing services company, 2017), which consists of 20 questions for the candidate to answer either using a web browser or with their mobile device. The outcome of this initial exam helps the human resources and the hiring manager with the selection process.

After successful hiring, the new employee is assigned to a team. Figure 7 illustrates the team structure. 'Location' refers to a geographical location, and teams are divided according to the product types. As seen in Figure 7, same types of teams exist in various locations. This allows certain services to be provided in close geographical proximity to customers' production/research facilities so that the customers' engineering team can easily access the company's service facility.

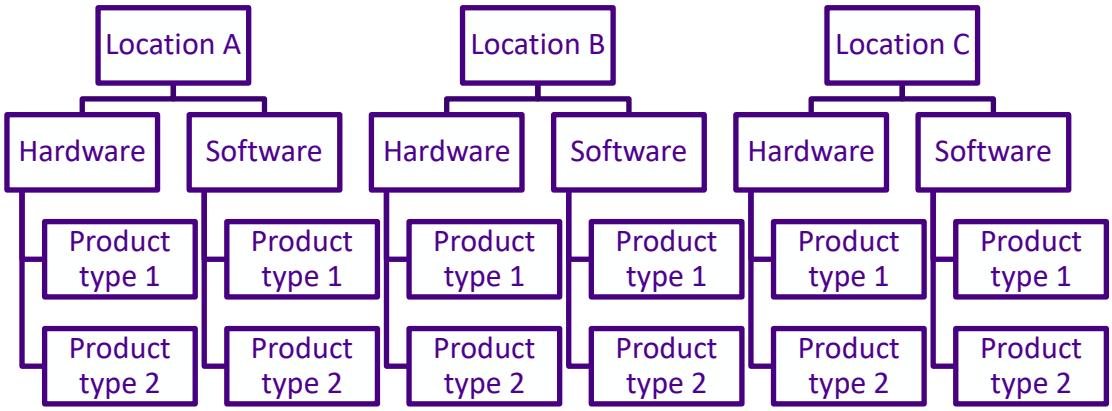

FIGURE 7. Team structure

After an employee is assigned to a team, they will be paired with a senior employee who acts as a mentor / trainer. Training is performed utilising the training plans in the global quality system, which consists of theoretical training (studies of specifications and test plans) and practical training (using test tools on actual products). After a certain amount of training, the employee takes a technical exam, which recently launched in 2019, that indicates whether they can be appointed as a qualified employee. A qualified employee can take on customer projects by themselves without constant supervision of senior staff. Training can also be offered to existing employees coming from other teams or from other countries. The same training principles apply to both new and existing personnel.

An employee is prepared to start offering services to customers after completing the training, but when exceptions arise, only experience can help the employee propose a solution to the customer. This experience is typically in form the of tacit knowledge from a senior employee, who can advise the employee on how to handle the issue at hand by showing them how similar issues have been handled in the past. The improvement of tacit knowledge management would address this exact scenario by standardising the methodology how a person can find the information and how to implement the information.

Based on the documents in the quality system, the company's service offering is somewhat standardised but the experience of the employee ultimately impacts the quality of the offering. Customer can ultimately lose more time when service is offered by an inexperienced employee than when it is provided by a senior employee. Even with a perfect knowledge management system, the service turn-around time with inexperienced staff would be longer than that with senior staff because more junior employees have to spend time finding information from the knowledge management system or asking senior employees. This is unavoidable and is alleviated only by the growing expertise of employees.

3.3 Chapter summary

As seen in this chapter, the company investigated in this study has a solid foundation of the knowledge management in form of quality management system and technical documentation maintained by employees. While experienced employees are delivering good service to customers, time required for junior employees to reach desired level of service is lengthy. In order to improve the knowledge conversion process and ultimately to answer the research question, next Chapter 4 introduces the research methods used to gather perspective from the staff regarding the knowledge management currently in use.

4 RESEARCH METHODOLOGY

4.1 Research process

This research consists of three segments: a theoretical part, an empirical part (interview and questionnaire) and the results, as seen in Figure 8 below. In the theoretical part, various research theories and approaches are introduced. Additionally, the questionnaire, interview and the Delphi method are discussed in this chapter. The empirical segment refers to the conducting of the questionnaire, the interview and the Delphi method. The final part, Chapter 5, which is the results, draws from both the theoretical part and empirical part and summarises the results to be further analysed in Chapter 6, Discussion.

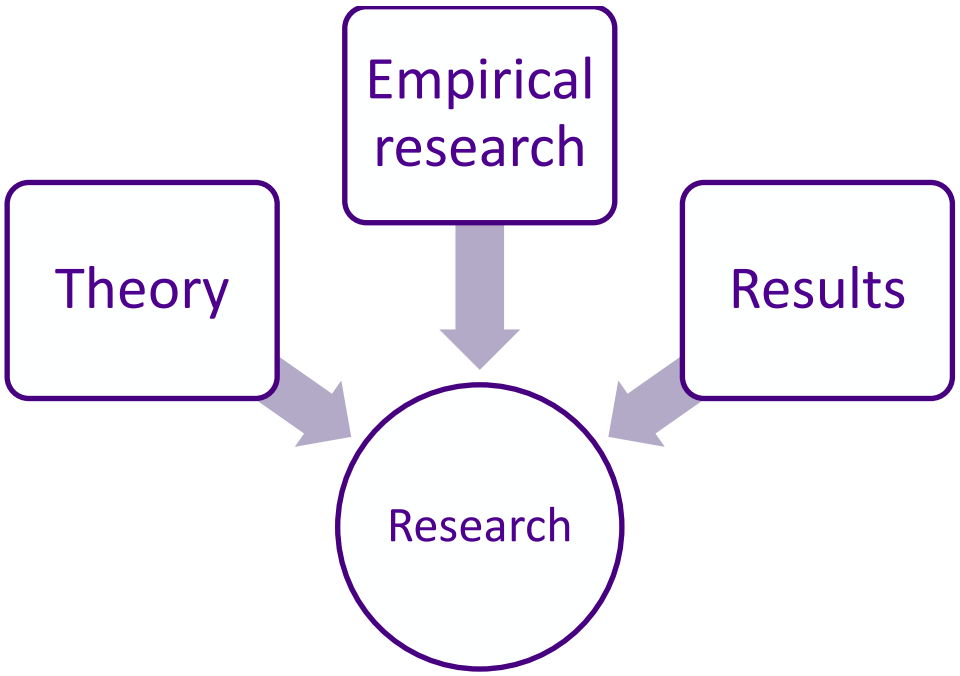

FIGURE 8. Research structure

4.2 Research approach

There are various ways to conduct research. However, for academic purposes, the focus will be on quantitative research, qualitative research or a mix of both (Creswell, 2003, pp. 12,13). For this study, the majority of the research conducted utilised the qualitative approach, as the scope of the research, focuses on human experience and behaviour. Considering the services offered by the company, this approach was the most suitable.

According to Creswell, a quantitative approach involves researchers obtaining numerical data from measurements, collecting statistical data or using postpositivist claims (cause and effect, hypotheses, questions) for knowledge development. A qualitative approach means collecting and analysing data from individuals using open-ended questions, making knowledge claims and by observing people's activities. The qualitative approach provides the point of view of the participants of the study. A mixed approach involves researchers making knowledge claims on a pragmatic level, gathering data from both numerical information and text information. This approach represents both quantitative and qualitative information.

Some of the previously mentioned possible data-gathering methods are introduced in Table 2; the actual methods applied to this research are indicated in section 4.3.

TABLE 2. Data collection methods (Creswell, 2003)

Quantitative Research	Qualitative Research	Mixed Research
• Predetermined Instrument based questions • Performance data • Attitude data • Observational data • Census data • Statistical analysis	• Emerging methods • Open-ended questions • Interview data • Observation data • Document data • Audiovisual data. • Text and image analysis	• Both predetermined and emerging methods • Both open- and closed-ended questions • Multiple forms of data drawing on all possibilities • Statistical and text analysis

Furthermore, the comparison of the quantitative, qualitative and mixed research approaches is in Table 3.

TABLE 3. Qualitative, Quantitative and Mixed Methods Approaches (Creswell, 2003), modified

	Qualitative Approaches	**Quantitative Approaches**	**Mixed Methods Approaches**
Philosophical assumptions	Constructivist/Advocacy/Participatory knowledge claims	Postpositivist knowledge claims	Pragmatic knowledge claims
Strategies of inquiry	Phenomenology, grounded theory, ethnography, case study and narrative	Surveys and experiments	Sequential, concurrent and transformative
Methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numerical data	Open- and closed-ended questions, emerging and predetermined approaches and quantitative and qualitative data and analysis
Practices of research	Positions him- or herself Collects participants meanings Focuses on single concept or phenomenon Bring personal values into the study Studies the context or setting of participants Validates the accuracy of findings Makes interpretations of the data Creates an agenda for change or reform Collaborates with the participants	Tests or verifies theories or explanations Identifies variables to study Relates variables in questions or hypotheses Uses standards of validity and reliability Observers and measures information numerically unbiased approaches statistical procedures	Collects both quantitative and qualitative data Develops a rationale of mixing both data types Integrates the data at different stages of inquiry Presents visual pictures of the procedures in the study Employs the practice of both qualitative and quantitative research

4.2.1 Questionnaire

A questionnaire is one of a range of ways of getting information from people (Gillham, 2002, p. 2). An oral questionnaire is conducted by a surveyor performing face-to-face interviews to ask questions. The written version can be conducted in paper or online, with the latter being the preferred version for this study as it can cover multiple geographical locations and allow for ease of gathering results (Gillham, 2002, p. 6).

Questionnaires can be structured, semi-structured or unstructured. A structured questionnaire contains only closed-ended questions, which mean predetermined answers, (Gillham, 2002, p. 5), while an unstructured questionnaire contains mainly open-ended questions. Open questions are more difficult to analyse than closed-ended questions, hence they are only occasionally used in questionnaires (Gillham, 2002, p. 5). Semi-structured questionnaire contains both open- and closed-ended questions. The questionnaire type chosen for this study is semi-structured, as it allows for sufficiently focused questions while still enabling the respondents to answer in their own words. Questions chosen to be included in the questionnaire are intended to gather opinions from the participant and thus form a basis for the interview and the Delphi method.

When developing a questionnaire, there are two main parameters (Gillham, 2002, p. 15): “What are we trying to find out?” and “What are the specific research questions?”. Once the objective of the questionnaire is defined, we can proceed with the definition of the questions. It is important to know that a researcher may be biased in defining the questions based on the researcher’s own assumption of knowing what the issue is (Gillham, 2002, p. 17). When defining the questions, I have tried to avoid suggesting anything and rather just requesting for interviewees opinions. Only exceptions would be the questions one and two where the point of variability of the level of detail in the guidelines is presented in the question and interviewees are asked to provide their perspective on the matter. Questions one and two were defined as such due to the feedback from the recently hired staff in APAC-region mentioning complexity of obtaining the training on more than one skills. More details on the definition and conducting of the questionnaire is available in section 4.3.1.

4.2.2 Focused interview

A focused interview is often used in qualitative research, as it is a qualitative interview. Other alternatives would be an open interview or a structured interview. An open interview is generally not well suited to address specific topics as the interview tends to stay on a superficial level, and a structured interview would be too strict as the interviewer is not allowed to stray from the pre-set questions. This prohibits innovation, which could rise from additional questions from the interviewer. A structured interview is also more of a quantitative interview.

As described by (Edwards & Holland, 2013, p. 4) in their publication, a qualitative interview offers interactional exchange of dialogue and learning for both the interviewer and interviewee. As in any exchange of dialogue, the reactions and the personal context of the interviewer also contribute to the interview. Interviewees reactions are important as they may offer additional clues such as a certain attitude towards a specific topic. These reactions can be documented due to they may offer supportive data. In this study, I've taken into account the reactions from the interview in the results, either as direct comments or as observations.

4.2.3 The Delphi method

Prior to the Delphi method, the traditional way was to conduct round-table discussions among experts and have them arrive at an agreed-upon position (Helmer-Hirschberg, 1967). This had several drawbacks, such as being affected by group or social dynamics where the most vocal or dominant person would ultimately lead the discussion to the direction of his or her preference, making the round-table discussion effectively a confirmation of one individual's opinion.

As an improvement to the round-table discussion, the Delphi method was created by RAND Corporation (RAND Corporation, 2019) in the late 1950s to forecast the impact of technology on warfare. The study focused particularly on how future technological capabilities might be used by the military. The Delphi method is used to collect responses from experts as an iterative process. Information is collected via individual responses in questionnaires to avoid the influence of

group or social dynamics and then processed with supplementary information and feedback sequentially. The goal of the Delphi method is to reduce the variance of responses and arrive to a conclusion or consensus (Helmer-Hirschberg, 1967). In practice, the facilitator (the person coordinating the Delphi method) creates a questionnaire in the first round and sends it to the participants, who will complete it and return to the facilitator. The facilitator then analyses and summarises the answers on which the questionnaire in the second round will be based. This iteration process can continue as many times as necessary until a consensus is found or opinions began to polarise around two positions. At minimum, two rounds are necessary. The facilitator then summarises the results. As indicated in (Gillham, 2002, p. 310), the Delphi method provides useful way of providing data from behind-the-scenes but requires upfront and continuous work from the researcher in synthesizing and summarizing the data. The inherent risk with the Delphi method is the researcher failing to correctly synthetize the answers, potentially stalling the feedback process prior the consensus is reached.

For this study, as I wanted to gather the consensus from the experts, I conducted a modified version of the Delphi method. This was done in order to spare time for the experts who have strict schedules to follow. Instead of repeating the cycle with the experts, I started with the questionnaire which was answered by a mixed group of engineers and experts. Then the interview was conducted with the summarised answers from the questionnaire with experts and activity manager chosen by their field of experience and geographical location. This variant of Delphi method has a risk of the experts not agreeing on the content provided by the first round of answers, which would stop the Delphi method, however in this research such issues didn’t occur. Also, as the questions asked were closely related to the everyday work of both the experts and junior level employees, information was relevant to all participants. More details on the definition and conducting of the Delphi method is available in section 4.3.3 and some thoughts for possible further studies in Chapter 6 .

4.3 Empirical research

The empirical research started with the planning of how to conduct the actual research with the personnel. Feasible options considered were face-to-face and group interviews, phone or Voice Over Internet Protocol (VOIP) interviews and questionnaire in paper or online. Decision was made to proceed with usage of Office 365-integrated tools as much as possible to avoid time consuming post production in transcribing and editing. Online semi-structured questionnaire was chosen as the starting point as this format offered good global reach for all staff of the testing department and efficient result gathering and presentation, also this questionnaire type allowed answering using various types of devices, such as personal computers, office computers or mobile devices. Following with the results gathering from the initial questionnaire, focused interviews were conducted either via VOIP or face-to-face. Cloud-based data management (for data repository, except for the confidential results which were stored only on the author's computer), word processing and other Office-related tools are used in the company and they were also used to create this study. These solutions offer an integrated survey-feature, as introduced in section 4.3.1. The same tool is also used in the training exams, which I have introduced in section 3.2.1. The questionnaire and focused interview combined together acted as a variant of Delphi method.

4.3.1 Conducting the questionnaire

An online questionnaire with 11 questions (see appendix 1) was sent globally as a Office 365 Forms -link to all testing department employees. Forms allows results gathering either anonymously or by using the name of the respondent based on their Office 365 login account. I chose to proceed with the tracking of the personnel login account as this enabled me to identify the location of the respondent for geographical distribution, no other info of the respondents is shared in this thesis. I could have indicated manually fillable field for exact department location but I preferred the automatic way to simplify the questionnaire filling. The topics chosen to be included in the questionnaire were created from my personal experience, feedback from the staff over the years and observations at the company, especially linked to current way of knowledge management (see section 3.1) and

staff training (see section 3.2.1). The purpose of the questions was to probe the behaviour of the individuals. The questions were also designed to make them think how and why things are done currently and whether there would be any room for improvement. The questionnaire had three themes, first focusing on working guidelines and documentation currently available for employees, second focusing on interaction with colleagues or senior personnel and the third one focusing on customer's perspective of the service provided and potential improvement suggestions.

As the tacit knowledge is linked to the individual, the personnel's answers to the question would mirror their own experiences with their supervisors or senior employees (regarding the training and support). Hence, valuable feedback covering both their opinions and practical examples are provided. The questionnaire was sent to 86 employees (members of the testing departments in all global testing locations in 2019) and seven responses were received. All of the responses were deemed valid as they contained sufficient amount of details and in addition they represented good geographical and experience distribution. Respondents varied from recent hire with few months' experience to senior employee with more than a decade of experience. This difference in experience was valuable component as the respondents were therefore either recently receiving training or have offered trainings in the past. Geographically the distribution was three respondents from Europe and four from Asia-Pacific. A list of participants to the questionnaire is shown in Table 4.

TABLE 4. Questionnaire participants

Identification	Location
Participant A	France
Participant B	France
Participant C	France
Participant D	Taiwan
Participant E	Taiwan
Participant F	Taiwan
Participant G	China

4.3.2 Conducting the interview

The amount of interviews needed for sufficient coverage was determined by the fact that interviews should continue until the interviewees are not offering any new data. (Edwards & Holland, 2013, p. 66) mention the range from six to 50, depending on the purpose of the study. In this thesis, I've chosen six interviews as this number represents good global penetration in the company without taking too much time for the experts or activity managers. The geographical split of the interviewees was three for Asia-Pacific and three for Western countries and I chose the interviewees based on my experience and knowledge of the teams globally. I have worked with all the interviewees in some projects or analysis and one of the interviewee was working in my department at the time of the interview. None of the interviewees rejected the invitation but scheduling was adjusted for few interviews due to lack of availability.

All but one interviewee were experts, one interviewee was activity manager. I wanted to include at least one activity manager to the interviewees as the activity manager, as described in section 3.2, has typically been expert before their current position and in their role as activity manager they are responsible of the training of the whole team. Thus the feedback from activity manager offers more wide perspective, yet focused on the technical team. All had wide range of technical expertise and several years of experience and also experience working in several geographical locations, thus they were able to offer perspective which was not limited to their specific field or location. As described in section 4.2.3, the contents of the interview were formed from the summary of the questionnaire answers. Persons being interviewed were asked the same questions as in the questionnaire and then their answers were progressively added to the conclusion.

Interviews were conducted in English, as it is the most common language in the company. Despite English being a second language to the majority of the employees in the company, English is the company's main working language, especially with written materials. Hence, the usage of this language was not considered as a hindrance to the outcome of the interview. Utilising only one language also helped to create the summary of the interviews without having to resort to

translation. Inevitably, some people were more adept in using English as a second language, and thus the outcome of the interview can depend on the language skills of the person. The questions used in the interview are in appendix 2.

Interviews were conducted in two ways: as a physical interview or as an online interview. The atmosphere of both the physical and online interviews was casual as both the interviewee and interviewer knew the subject and the purpose of the interview well. Recording was informed prior to the interview and all interviewees agreed to recording. Physical interviews were conducted in meeting rooms of the company in various geographical locations and recorded using a sound recorder application on mobile devices. Reliability of the sound recorder application was tested prior to the interviews and no loss of data occurred. Online interviews were conducted using Microsoft Teams with only sound enabled and recorded using the recording feature. As the usage of Microsoft Teams and other VOIP-tools is common in the company, all participants were accustomed in usage of either a headset or a meeting speaker with microphones. Video was disabled in the interview as the company rarely utilises video calls. On average, the time per interview was approximately 40 minutes.

Interviews were transcribed to text format using an online audio-to-text service. This conserved time as listening and transcribing the material by myself would have utilised a considerable amount of time. I experimented with two different approaches in transcribing: computer-generated transcribing and human-generated transcribing. Computer-generated transcribing was tested with two different suppliers, but the accuracy and pricing had considerable variation. Delivery speed of computer-generated transcribing service was usually in minutes, whereas human-generated transcribing would take hours. When utilising computer-generated transcribing for two or more persons talking using their non-native language, the accuracy became quite poor. Therefore, for such meetings, I resorted to a human transcribing service that achieved almost perfect accuracy. The only issues were the industry-specific terms that, understandably, cannot be known by the general population.

After transcription, the answers were collected and summarised to draw conclusions. The workload for each interview analysis was roughly one hour as the usage of the transcribed text material was efficient. Points made in the interviews were illustrated in individual visual mind-maps for each interviewee, then a summary mind-map was made which aims to link the similar topics from multiple interviewees. I used an online mind-mapping tool (Coggle, n.d.) for this task which was proven effective in the courses of my studies. The mind-map was then compressed to a more readable format and findings as such are presented in section 5.3. The compressed mind-map is also attached in appendix 5. Some information of the interviewees can be seen in Table 5, but details have been redacted to ensure confidentiality as the interviewees provided their personal opinions.

All except one interview were conducted as individual interview. The exception for the two-person interview was made due to inconvenient time zone and scheduling. In the end both interviewees provided their own perspective, which was seemingly not affected by the other person so I considered this approach being valid. It was even useful to see some of the answers of the interview pair contradicting each other.

TABLE 5. Interviewee participants

Identification	Location
Participant H	Korea
Participant I	Korea
Participant F	Taiwan
Participant K	France
Participant L	Canada
Participant M	Canada

4.3.3 Applying Delphi method

For the purposes of this research, a questionnaire sent to the global testing department and answers received served as the round one of the Delphi method

and the interviews served as the second round of the Delphi method. The first interview was conducted using the summary of the questionnaire answers and further interviews were conducted with additional data from the previous interviews. The conclusion was drawn from both the answers to the questionnaire and interviews and the conclusion also focuses on topics with sufficient and actionable information.

Participants for the Delphi method can be seen in Table 6. The questionnaire was sent to 86 participants globally and the response rate was 8%, with seven responses received. The interview was conducted with six participants, making the total quantity to the Delphi method as 13 participants out of 86 (15% total participation, as the interviewees were also part of the questionnaire mailing list). Type of responses received indicate the topic and the questions were well received and respondents provided useful insights. As global penetration was also sufficiently wide (two countries, Taiwan and France, with four participants, rest of the countries with fewer participants), I consider the results are valid for the whole company.

TABLE 6. Delphi method participants

Qty	Location	Response type
3	Taiwan	Office 365 Forms
1	China	Office 365 Forms
3	France	Office 365 Forms
2	Korea	Interview
1	Taiwan	Interview
1	France	Interview
2	Canada	Interview

5 RESULTS

5.1 Findings from theory

Based on the results gathered, knowledge conversion process applied in the company is closely following the processes mentioned in section 2.3.1 and defined by (Gold, et al., 2001) and (Nonaka & Takeuchi, 1995). This is clearly visible in the respondents with junior-level experience as they indicate strong reliance to senior colleague's help when the documentation is not sufficient (socialization and externalization). The answers from technically senior level employees indicate combination and internalization of the knowledge. Gold's knowledge infrastructures (technical, structural and cultural) are also reflected in the responses as technical and structural portions in the company are fundamentally sufficient but important details regarding the efficiency of for example document validation could be improved. Cultural infrastructure reflected by the responses indicate good collaboration within the teams when for example documentation is not sufficient or requires validation by additional personnel.

Type of redundancy, in section 2.8.1, by (Nonaka & Takeuchi, 1995) can be extracted from the responses as implemented in the company. If senior colleague is not available to provide immediate answer, another colleague, either in the same or other location, can provide the answer. Another aspect of redundancy, free access to information, is also visible in the results as even though the information may not be available in one document, it typically can be located from other document.

5.2 Findings from the questionnaire

The length of the answers provided to each question indicated how each person processed the question; some offered highly concise statements while others provided preparatory information before their actual answer. The nature of the answer also can act as an indicator to the person's mind-set as a highly concise statement can indicate a lack of interest to the question itself.

The company has not previously utilised queries or questionnaires globally within the technical scope, so this may explain the low answer volume. There were two follow-up requests sent after the initial email, encouraging personnel to answer. These follow-up requests yielded only to two more answers. Some answers provided quite an interesting split between Western (European / American) and Asian approaches, which is important to realize when implementing any global methods or procedures. Summary of the answers is provided in appendix 3 and all answers (compressed with redundant answers removed) are provided in appendix 4.

As introduced in section 4.3.1, the questionnaire had three themes. The answers provided on the first theme, guidelines, indicate common opinion that there's sufficient amount of detail available overall but it requires cross-checking with multiple documents and potentially verifying with a senior colleague. None of the respondents stated they couldn't find the information they require to perform their work. Senior personnel were accustomed to handle multiple documentations whereas junior personnel were more bothered with the various documents. Summary of answers is indicated in Table 7.

Generally, it seems not feasible to create one uniform standard for the internal guidelines due to variable level of information at the source, testing authority. As mentioned by one participant, some authorities have more documents available for reference than others (Participant F). This does have a direct influence to the guideline level of detail as the person responsible of the guideline will have to work more to create sufficient guideline when reference documentation is not at required level of detail. Potential solution, as introduced also by Participant F, for this would be to define three levels of details for guidelines, each associated with corresponding authority requirements. This would ensure sufficient level of detail where needed and avoiding unnecessary documentation work where not necessary.

TABLE 7. First theme answers (compressed, with redundancy removed)

Question No.	Answers
1	Internal GDL, authority documents, report template and expert meetings are together enough to perform tests. Sufficient detail but time consuming to search. Better with illustration. Very good but confusing. Yes and no, depending on the author.
2	Yes, but knowledge (why something is done) is missing Yes, some more detailed than others. Yes, mature guidelines are detailed whereas new guidelines lack details. Three variable levels per authority requirements.
3	No but information dispatched in different documents in different locations. No but will ask colleague if something missing.

In second theme, interaction with colleagues, senior personnel's answers indicate no issues with interaction but for junior personnel, the progress on their work may rely on availability of senior personnel and efficient knowledge sharing. Summary of answers is indicated in Table 8. One of the participants complained about the availability of direct manager. The challenge of performing efficiently with good competency (Participant A and B), requires balancing between the two variables (efficiency and competency). In order for junior personnel to perform efficiently, they require either time to obtain the knowledge or time during the provision of the services to ask from a senior colleague. The former takes more time in the training phase but produces overall more competent personnel, whereas the latter takes less time but relies more on senior personnel during the services to act as support.

Sharing the answer directly (when requesting assistance) was mentioned by two participants, both junior personnel working in Asia-Pacific region. Sharing the source for the solution, instead of the direct answer, was mentioned by three participants, one junior personnel working in Asia-Pacific region and two senior personnel working in Western region. These responses indicate a differing course in

mentorship where Western approach favours indirect training and Asian approach direct training, but naturally the findings can be linked only to these specific individuals, not necessarily applicable to whole staff globally.

TABLE 8. Second theme answers (compressed, with redundancy removed)

Question No.	Answers
4	Test specification unclear and method open to interpretation. Balance between occupancy rate and competence improvement is a hard challenge.
5	Wait for availability. Ask QAP-owner. Ask manager.
6	Sharing opinion. Answer and indicate where the answer was found. Share experience.

In the final theme, customer perspective and improvement suggestions, respondents indicated common approach of working with customer to understand their needs and working together to offer suitable testing service. Senior personnel's concerns in this final theme were more related to consulting with customer to drive them to correct direction whereas junior personnel were more concerned of providing the correct standard service. In all responses, it was clear that the respondents understood the importance of correct and efficient customer service, regardless of the skill level of the respondent.

Related to improvement suggestion, only one respondent had received improvement suggestions from customers. Lack of improvement suggestions from customer can be linked to either the type of services being offered by the respondent (some services can only be offered with specific tools, regardless of by who and by where the service is provided) or by the customer service approach of the respondent. Three respondents provided improvement suggestions to current processes, related to both technical and knowledge management. The responses indicated suggestions similar to the currently ongoing improvement projects by

the company's operational efficiency team, in example tool automation and linking the tools more efficiently to the project management database.

The time needed to keep internal knowledge sharing database updated was raised by Participant B. This is common issue with knowledge sharing as the payoff from taking the time to share the material should be higher than the time spent. Potential solution for this could be rewards system, as mentioned in section 2.10. Summary of answers is indicated in Table 9.

TABLE 9. Third theme answers (compressed, with redundancy removed)

Question No.	Answers
7	Understand customer requirements. Product developed according to test tool and not according to specification. Lack of experience wastes customer time and money. Question is beyond my ability. Don't know how to operate device or tool. Difference between debug and type approval. Issue encountered not referred in the specification.
8	Ask more details from customer to understand their needs. Precision. Ask for experienced persons' opinion.
9	GDL in .docx-format, review procedure too complex. WIKI. Adding automation in tools. Integrate tools with project management database. Engineers shall have more spec knowledge but training time is usually not enough.
10	Try with another tool. Tool uses too many resources on testing computer. Performance tool LED trigger improvement.
11	Share the issues with team regularly. Take sufficient time with new colleague. Engineers need to suggest improvements to QAP-owner.

5.3 Findings from the interviews and from the Delphi method

Interviews and therefore the second cycle of the Delphi method were all conducted with senior members of the company so the quality of the answers was high. Their responses provided valuable insight and all the interviewees placed emphasis on good customer service. In the following sections the comments for the three themes (as done in the section 5.2) obtained from the interviews are analysed. First interview was started with the summary from the questionnaire

answers, as introduced in section 4.3.3 and following interviews continued to add material to the questionnaire answers.

For the first theme, guidelines, the variability of the guidelines was mentioned by three interviewees, by both the persons responsible for the guidelines and by the persons utilising the guidelines. Only one interviewee (Participant I) didn't consider the variability a limiting factor, however the person has been involved only in specific activity through the career, thus this answer is applicable only for the participant's field of work. One of the interviewees (Participant K) questioned which exact technical document was under observation, this answer was avoided to keep the discussion on general level. The same interviewee raised a question whether the company should keep guidelines light and training strong, or vice versa. This proposed question was asked from other interviewees and the answers were in favor of strengthening the training without sacrificing the guidelines.

Technical owners of any given activity at the company are individual senior members of the team, who are spread globally at the company. Since requirements for the content of the guidelines is not sufficiently standardized, they can generate content based on their own way of thinking and also by their exposure to the authority. This variability causes issues for new members joining the company or existing personnel training for new activity because they have to spend significant time during their training to search for information that is not necessarily mentioned in the guidelines. Updating the existing guidelines was also mentioned being laborious, both from the content creation and editorial perspective. In addition to the creation and modification of the content, the validation process is mentioned being heavy and time-consuming. Overall, the level of detail in the guidelines and supplementary documentation also depends on the authority requirement, if the authority doesn't have explicitly detailed requirements, the document owner typically wouldn't add very detailed information in to the document.

In second theme, interaction with colleagues, insufficient training time or training scope was mentioned by five interviewees (Participants H, I, J, K and L), being the most common shared topic. As these personnel are the one who are typically responsible of delivering the training, they can see the time allocated for training

is typically not sufficient due to business requirements. For company benefit, junior level employees shall be productive as soon as possible and this pressure can impact the quality of the training they receive. If the junior level employee would be allowed to spend more time in training before they are placed in the actual production work, the future workload of the experts and activity managers would decrease and consequently customer service would be more efficient as the junior level employee could handle most of the challenges encountered. As there are variable levels of technical understanding in the beginning of the training, the training duration needs to be calibrated individually to each person. The technical exam, introduced in section 2.3.1, is helping to streamline the technical level of the employees and should be encouraged to use actively.

In the final theme, customer perspective and improvement suggestions, three interviewees (Participants F, K and M) mentioned video recording as a support material. This practice is used selectively in some departments and locations, but has not been adopted globally, most likely due to time required to produce the content of the video and lack of guidelines for the recording. For company to get started using the video, initial guidelines or best practices could be created. Participant K suggested to use the current quality system to track customer suggestions and improvement ideas, this has been initiated by the quality team in January 2020 following similar improvement idea from previous internal meetings. Two interviewee (Participants M and F) have received suggestions from customers and both were related to the tools used in the company. Tool improvements for certain tools are in progress, initiated in early 2019 and these improvements will address most of the feedback from the customers.

Session sharing and lessons learned was proposed by three interviewees (Participants F, K and M). By enhancing this the company would be able to leverage the global knowledge and avoid issues happening repeatedly in other locations and improve operations. As the company has a global quality system in place which handles for example constant quality improvements, the sharing of lessons learned could be done either by using the same quality portal or by Microsoft Teams. As mentioned in the findings from the questionnaire, the information input time for the shareable material could be compensated for example with rewards system, as mentioned in section 2.10.

5.4 Conclusion

This research was interesting and produced several implementable ideas, with some easy to implement and some more complex to implement. Generally, the fragmented structure of the guidelines and processes is something that should be addressed as a priority. Unfortunately, this is also a highly complex task. However, upcoming improvements regarding the database migration to a cloud-based tool may help in reducing the complexity.

One questionnaire answer indicates the complexity of the information required to perform duties:

> *For me with internal guideline in QAP, authority guideline, internal database, report template and finally meetings with expert for each spec/testplan/guideline evolution of the documentation, the documentation is enough to perform tests.* (Participant B).

This complexity could be reduced by introducing variable levels of detail to the guidelines, as typically more mature authority has more detailed requirements, hence the guideline for such authority would cover additional details.
Several answers mention the need of training or onboarding improvement and information sharing:

> *In fact, I will prefer the engineer could have more SPEC knowledge or a clear logic than only following the documents when debugging or testing. Sure, they have to read those documents when training but the training time is always not enough.* (Participant F).

> *By experience nothing is better than taking time when a new colleague arrives to use as soon as possible the existing documentation. Teach the objective of each document to helps him to find alone the answer, it takes time on the beginning but improve significantly the efficiency.* (Participant B).

> *In general there is enough details in GDL to perform the tests. But the knowledge (why I am doing this) is not always present, so the operator do the actions without understanding why*. (Participant A).

Training is something what the company already does but as the outcome of this research work indicates, training is typically insufficient and done too quickly. Efficient solution for this would be for example to allow sufficient time for junior level

employees to work under mentorship of a senior level employee. Information sharing is something which the company has various tools and platforms at its disposal but require direct usage instructions, starting with the Information Technology team, and sufficient motivators for the staff to gain widespread usage.

Generally, to encourage staff to continue improving and especially to encourage knowledge sharing, a reward or acknowledgement system could be established to provide rewards to those who contribute to the database. This topic has been discussed with various managers on several occasions with variable levels of traction. These rewards could be monetary, annual leaves, attendance to conferences paid by the company, self-training time or training courses paid by the company. Another point to consider are the performance reviews, as a motivator or trigger for personnel to contribute to the knowledge generation, but this can impede knowledge sharing due to different regions placing different weight on knowledge creation compared to productivity objectives.

The addition of video materials was mentioned several times so this will be a worthwhile topic to address, as it can be used both internally within the company and externally with customers. However, creation of video materials takes time away from productivity so the company would need to analyse the cost and benefit of the findings. Generally, for internal use, mobile phone or screen capturing should be used for efficient recording, using these ways the material could be easily uploaded to for example Microsoft Stream for sharing. More widespread usage of video recording could be a good topic for another thesis, perhaps to study the usability with both internal and external users. Summary information regarding the recommended action priorities and their status is indicated in Figure 9.

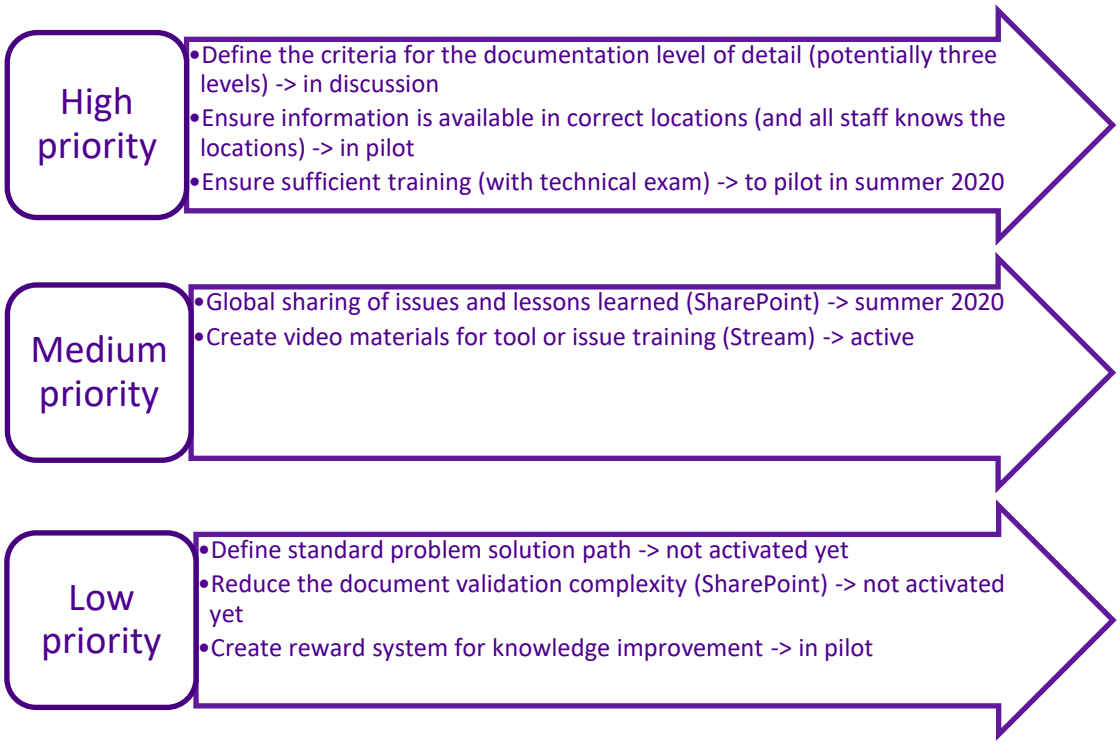

FIGURE 9. Summary of recommended action priorities and their status

Starting in March 2020, the piloting and / or implementation of some of the recommend actions has begun. In High priority actions in Figure 9, criteria for the documentation level of detail has been discussed with some of the QAP-owners and will require additional clarification before deciding the details of the actions to be taken. Second High priority action, information availability to all staff has been addressed as added item in the staff training plan for some activities, listing the specifically needed documents or other source of information and their location within the company network. No new staff has been hired during the beginning of 2020 so the impact of this modification to newly hired staff is not yet known. As the modification addresses some of the concerns raised in the answers for questionnaire question 3, it will benefit the staff having recently started training this corresponding activity and thus it will improve the information availability. Last High priority action, sufficient training, will be discussed with the trainers of activities during summer 2020 as this requires the trainers to adjust their training plan timing. After this discussion the detailed steps will be taken by the trainer, taking into account the company management guidelines.

In Medium priority actions, global sharing of issues, a Sharepoint-site has been requested to be created and this will be used to host the items from the second medium priority item, estimated in summer 2020. Second item in Medium priority actions, video materials, has been implemented with some activities during the spring of 2020 to address the training needs due to current travel limitations enforced by several countries. Most recent case was in mid-May for test tool remote install at customer site, utilising video call for remote viewing of the tool and Microsoft Teams used for document sharing. As most of the training between countries or regions has been shifted to webinars, recording of the webinars have proven to be an efficient way of sharing the knowledge. The recorded webinars are currently shared by the host as email-link to the participants who will then further distribute to persons in their teams.

In Low priority actions, reward system for knowledge improvement was discussed in the annual meeting in January 2020 with the Head of Quality Management and it was deemed useful and will require clarification of the reward type from the company management. For any reward, it must be budgeted and thus it has to be taken into account for annual budgeting exercise, typically commencing in the fourth quarter of each year. Other two items in the Low priority have been introduced to the company management with no further actions.

In conclusion, two of the recommended actions have been already implemented at some activities and the other items are planned to be addressed in the summer 2020. With these implemented actions, the company will be able codify some of the tacit knowledge from the employees and thus increase its operational efficiency. Follow-up questionnaire is planned to be created in the third quarter of 2020 to measure the impact of the actions taken.

6 DISCUSSION

The goal of this thesis was to find out an answer to question: How can tacit knowledge be efficiently managed, retained and shared? The research, starting with the theories based on various well-researched sources and empirical research conducted as qualitative research, started by referring to the existing tools and strategies in the company and reflecting those to the staff actually using them. Based on these findings, the company shall enhance the personnel contribution to the knowledge management system with more defined structure of the guidelines which are a major source of knowledge in the company.

As the implementation of some of the topics discussed in the interviews already started during the course of this thesis, the outcome of the research work seems well aligned to the company. As for the further work to be done, improvement of the company processes (continuous quality improvement) is always an ongoing task in the company and thus this research serves also as a foundation for future improvement topics within the company.

From my own perspective, the research work went well. The initial steps of the work took ample time to find the correct angle of the approach. After finding the suitable approach, the following steps were easier to process. Data gathering was surprisingly complicated and time-consuming, as it involved some staffing changes and a lack of availability from the respondents. The ongoing workload of the respondents affected the quality of the answers significantly, so the timeframe of when to approach personnel with questions needed to be chosen wisely. Forecasting availability also needs to be taken into account. The topic of knowledge management, being an umbrella term, always requires calibration to match the intended environment. It is, however, a well-researched topic and thus source materials and examples are plentiful and easily accessible owing to a wide range of research already conducted.

From the company’s perspective, tacit knowledge management will require investment in both time and resources, specifically manpower. This is because the persons most capable of updating the knowledge management system are also

involved in daily operations. Thus, there will be a drop in production efficiency during the times when the knowledge management database is being accessed and contributed to. By ensuring ongoing contribution to the knowledge management database, the company can ensure that all offices globally are coordinated and services are being offered in a uniform way. For the company to enjoy sufficient knowledge management, it would be wise to first clarify the aim of knowledge management to the whole organisation. If knowledge management is properly integrated to the company, all cross-functional departments will enjoy the benefits.

For further studies, response bias could be an interesting topic to delve into, with a larger response group and dedicated analysis. As I used Office 365 account name tracking in the online questionnaire, it would be interesting to compare the answer percentage to a fully anonymous questionnaire. In such comparison the question types would have to similar for validity. The Delphi method would also be more efficient when used with larger sampling size, specifically more interviews and interview cycles. The Delphi method could also be conducted with purely using expert staff, following the original purpose of the Delphi method. All of these could be done either internally or by utilizing external company. In addition, during the course of writing this thesis, laboratories at the company seem to be working more like a production line rather than a specialised testing services provider. Upcoming new activities will be welcome to the staff; following the production line analogy, when staff is performing the same duties all the time, fatigue can manifest itself. Also leveraging operational excellence team even further could be investigated. As this team is already involved in global operations and has performed several optimization tasks, increasing their involvement to technical and quality standardisation would be logical. The follow-up of implementation of the recommended actions could also provide to be an interesting topic.

The purpose of knowledge management is not just to improve for improvements' sake but also to improve customer's experience through more efficient services and more global coordination. Efficient services increase a company's profit margin by decreasing the cost of services performed, and satisfied customers lead to increased revenue and a more projects in the future. As the company studied in this research already has a solid foundation of knowledge and selection of

suitable tools available, efficient tacit knowledge management is just a matter of definition, fine-tuning the processes and engaging the staff to fully take ownership of their respective areas of expertise.

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8 APPENDICES

Appendix 1. Email for the initial questionnaire (redacted)

Subject: Lab survey, tacit knowledge management

Hello all,

I am studying how labs could enhance/improve tacit knowledge management.

If you can spend few minutes to answer the above survey, your answers will be used to define future GDL-improvements, OE-improvements and SharePoint or other tool usage definitions.

Questions:

1. Are the testing steps detailed sufficiently detailed in the guidelines? Please provide some examples on deficiencies.
2. Is there a difference in level of detail between different guidelines? Please provide some examples.
3. Is there any information missing which you would need to have access in order to perform your work?
4. Are there situations where you don't know what/how to do and you cannot find information so you need to check with senior colleague?
5. If the senior colleague is not available to answer, what do you do?
6. If the senior colleague is available, how will he/she typically assist you?
7. What are the biggest challenges when working with a customer?
8. How do you handle those challenges?
9. What would you change in current GDL’s, SOP's or other quality procedures?
10. Have you received suggestions from customers about tools or procedures?
11. Do you have suggestions on how to improve tacit knowledge management in the labs?

Much appreciated for your time, best regards, Olli-Pekka

Appendix 2. Interview questions

Questions:

1. Are the testing steps detailed sufficiently detailed in the guidelines? Please provide some examples on deficiencies.
2. Is there a difference in level of detail between different guidelines? Please provide some examples.
3. Is there any information missing which you would need to have access in order to perform your work?
4. Are there situations where you don't know what/how to do and you cannot find information so you need to check with senior colleague?
5. If the senior colleague is not available to answer, what do you do?
6. If the senior colleague is available, how will he/she typically assist you?
7. What are the biggest challenges when working with a customer?
8. How do you handle those challenges?
9. What would you change in current GDL’s, SOP's or other quality procedures?
10. Have you received suggestions from customers about tools or procedures?
11. Do you have suggestions on how to improve tacit knowledge management in the labs?

Appendix 3. Summary of questionnaire answers

No.	Question	Answers
1	Detail level of guidelines	Typically not sufficient by itself, require supplementary information.
2	Difference between guidelines	Depends on scheme requirements and QAP owner
3	Missing information	Information is generally accessible but from various sources.
4	Need to verify with senior colleague	Information available in the documents does not cover everything so verification with colleague is required.
5	Lack of availability of senior colleague	Consult regionally
6	Assist from senior colleague	Western approach is to indicate the source where to find the answer, Asian approach tends to indicate the answer or method directly.
7	Challenges when working with customer	Experienced staff worry about differences between spec and test plan, inexperienced staff worry about inability to answer to customers questions.
8	Handling challenges	Globally common approach is extensive dialogue with customer or colleague(s) to solve the challenge.
9	Changes proposed in Guidelines, Quality materials	Documentation update process (with validation) is too complex, leading to lack of timely updates. Processes are fragmented. Training time must be allocated for any updates.
10	Customer suggestions	Not often received but depends on relation with customer.
11	Tacit knowledge management improvement suggestions	Sharing of sessions & lessons learned internally between the locations & teams.

Appendix 4. Detailed questionnaire answers

Question No.	Answers
1	Internal GDL, authority documents, report template and expert meetings are together enough to perform tests. Sufficient detail but time consuming to search. Better with illustration. Very good but confusing. Yes and no, depending on the author.
2	Yes, but knowledge (why something is done) is missing Yes, some more detailed than others. Yes, mature guidelines are detailed whereas new guidelines lack details. 3 variable levels per authority requirements.
3	No but information dispatched in different documents in different locations. No but will ask colleague if something missing.
4	Test specification unclear and method open to interpretation. Balance between occupancy rate and competence improvement is a hard challenge.
5	Wait for availability. Ask QAP-owner. Ask manager.
6	Sharing opinion. Answer and indicate where the answer was found. Share experience.
7	Understand customer requirements. Product developed per test tool and not per spec. Lack of experience wastes customer time and money. Question is beyond my ability. Don’t know how to operate device or tool. Difference between debug and type approval. Issue encountered not referred in the specification.

8	Ask more details from customer to understand their needs. Precision. Ask for experienced persons' opinion.
9	GDL in .docx-format, review procedure too complex. WIKI. Adding automation in tools. Integrate tools with project management database. Engineers shall have more spec knowledge but training time is usually not enough.
10	Try with another tool. Tool uses too many resources on testing computer. Performance tool LED trigger improvement.
11	Share the issues with team regularly. Take sufficient time with new colleague. Engineers need to suggest improvements to QAP-owner.

Appendix 5. Interview mind-map summary